Thouless pumping in quasi-periodic lattices

Zixun Xu
上海交通大学

We investigate a non-interacting quasiperiodic Thouless pump in arbitrary spatial dimensions. The system consists of multiple periodic sublattices superimposed together, exhibiting quasiperiodicity in space and time. Our analysis reveals that the cycle-averaged current density can be expressed in terms of the sublattice wave vectors and the pumping rate. In the commensurate case, we derive exact expressions for (i) the number of bands within a band group and (ii) its total Chern number, with explicit dependence on the integer commensurability between the global period and sublattice periods. For localized initial states, we obtain a general formula for the drift velocity v of the wave packet center. Furthermore, when some sublattices are controlled by a rotation angle θ, the mapping $\theta \mapsto v(\theta)$ always lies in a two-dimensional subspace and forms a conic section. We construct continuous models in one and two dimensions to numerically simulate the pumping process. In the structure with quasiperiodicity in both space and time, we achieve directed and localized wave packet pumping. Particularly in two dimensions, by gradually rotating one sublattice, we demonstrate wave packet transport along curved trajectories. All numerical results show perfect agreement with theoretical predictions. The proposed scheme can be experimentally implemented on optical and ultracold atomic platforms.

Synthesis, structure and magnetism in a novel frustrated triangular lattice antiferromagnet

Yang Zhao
深圳国际量子研究院

Spin-1/2 triangular lattice (TL) antiferromagnets offer fertile ground for exploring the interplay between geometric frustration and strong quantum fluctuations, often resulting in exotic quantum spin states. Here, we report on the successful synthesis of high-purity polycrystalline of a novel Cobalt-based S = 1/2 TL antiferromagnet via the solid-state method. Rietveld refinement of powder X-ray diffraction data confirms the sample's phase purity. Magnetic susceptibility measurements reveal nearly overlapping zero-field-cooled and field-cooled curves, excluding ferromagnetic or spin-glass behavior, with no long-range magnetic order above 1.8 K. Extending magnetic susceptibility measurements to 0.4 K uncovers a distinct λ-type anomaly at TN = 0.61 K, evidencing an antiferromagnetic phase transition. Curie-Weiss(C-W) analysis in the 100 - 200 K range yields a C-W temperature Θ = -20.33 K, indicative of strong antiferromagnetic interactions. Isothermal magnetization curves exhibit a rapid rise in low fields, followed by a slow linear increase, suggesting a contribution from temperature-independent Van Vleck paramagnetism. These results establish the compound as a promising platform for investigating quantum magnetism in triangular lattices.

Antiferromagnetic half metals and anomalous valley Hall effects in two-dimensional Cr-based materials

Yuzhong Zhang , Yu-Zhong Zhang
同济大学

Using the density functional theory calculations, we predict that several monolayer chromium-based materials exhibit a triple-Q tetrahedral magnetic insulating ground state where anomalous valley Hall effect with giant valley splitting is discovered, and CrI3 bilayer and its corresponding series of 2D transition metal triiodides MI3 with M the transition metal atom exhibit A-type antiferromagnetic ground states where gate-induced half-metallicity can be realized. Our findings open a new avenue towards exploring monolayer materials for valleytronics and electric-field-controlled spintronics.

Discovery and characterization of various emergent quasiparticles across diverse crystalline systems

Junzhang Ma
City University of Hong Kong

When atoms are orderly arranged into crystals, a plethora of rich and diverse quantum states emerge, such as topologically nontrivial states, superconductors, charge density waves, and various quasiparticle excitations. ARPES is an instrument that can directly probe the electronic structure of solids. It not only directly detects the single-electron spectral function in crystals but also reflects quasiparticle excitations, energy gaps and their symmetries, and the interactions between electrons and other degrees of freedom. Focusing on these scientific issues, we use the state-of-the-art ARPES to investigate the peculiar electronic structures formed by the interactions among charge, orbitals, spin, and lattice, aiming to explore novel quantum states in condensed matter systems. In the talk, we will present our previous works of discovery and characterization of novel quasiparticles in various quantum systems including: Weyl fermions in TaAs, hourglass fermions in KHgSb, three-component fermions and Fermi arcs in WC and MoP, fluctuating magnetic Weyl fermions, non-trivial magnetic Dirac fermions and axions in EuCd2As2, and unpaired singular Weyl Fermions in GaPt; Our research also extends to studying new quantum quasiparticles induced by electron-electron or electron-boson coupling in condensed matter, such as investigating mobile excitons in quasi-1D metallic material TaSe3, Cooper pairs and polarons in Iron-based superconductor Ba2Ti2Fe2As4O, and different quantum novel states in Kagome metals. The quasiparticles in condensed matter often exceed the variety found in high-energy physics, and thereby deepens our understanding of quantum materials and reflects the profound emergent phenomenon that "more is different."

Direct Visualization of Domain Wall Sliding-induced Polarization Switching in Multilayer Graphene

Sihan Zhao

Zhejiang University

Electric polarization and metallicity are long believed not to coexist until the emergence of exceptionally rare material examples including the bulk polar metals and more recently two-dimensional (2D) van der Waals (vdW) materials such as 1T’ WTe2. The electric polarization for the latter represents a new and distinguishable paradigm in materials science and physics because its electric polarization states embedded in the conduction electron sea are able to couple with (and controlled by) the external electric field. However, the microscopic polarization switching process and mechanism in these 2D vdW metallic materials have not been experimentally observed and remain elusive. Here, we report the first direct experimental imaging of the microscopic mechanism behind electric-field-coupled polarization switching in a metallic system. Our gate-tunable nanoscale optical imaging identifies the robust coexistence of electric polarization and appreciable carrier densities in adjacent polar domains hosting opposite electric polarizations in a 2D elemental metallic material, tetralayer graphene. We directly visualize and verify that the sliding domain wall (DW) solitons confined at the middlemost interface are responsible for the polarization switching in tetralayer graphene upon the application of electric fields and mechanical forces. Our work provides the first direct visualization of domain wall sliding-induced polarization switching in 2D elemental carbon at room temperature, significantly expanding and advancing the research of “ferroelectric metal” initially dubbed by P. W. Anderson and coauthors in 1965.

Controlling quantum entanglement via chiral Majorana interference

Yanfeng Zhou
福州大学

The control over quantum entanglement is fundamental to the advancement of large-scale quantum technologies. Here, we propose a chiral Majorana interferometer to govern the entanglement in a hybrid device consisting of a magnetic topological insulator and chiral topological superconductor. We show that quasiparticles outgoing from the domain wall of a chiral topological superconductor possess Nambu spinor entanglement because of the interference of chiral Majorana modes. It is found that the outgoing state can be manipulated continuously from the maximally entangled Bell state to the separable state by tailoring the type, thickness, and length of the domain wall. Based on the Clauser-Horne-Shimony-Holt inequality, it is shown that the concurrence quantifying the entanglement is directly given by the maximal Bell parameter measured from the current-current correlators.

Revealing the Orbital Origins of Exotic Electronic States with Ti Substitution in Kagome Superconductor CsV3Sb5

Hui Chen
中科院物理所

The multiband kagome superconductor CsV3Sb5 exhibits complex orbital textures on the Fermi surface,making the orbital origins of its cascade of correlated electronic states and superconductivity a majorscientific puzzle. Chemical doping of the kagome plane can simultaneously tune the exotic states and theFermi-surface orbital texture and thus offers a unique opportunity to correlate the given states with specificorbitals. In this poster, we will introduce our recent work about revealing the orbital origin of a cascade of its correlated electronic states through the orbital-resolved quasiparticle interference, by substituting V atoms with Ti in the kagome superconductor CsV3Sb5. We analyze the quasiparticle interference changes associated with different orbitals, aided byfirst-principles calculations. We have observed that the in-plane and out-of-plane vanadium 3d orbitalscooperate to form unidirectional coherent states in pristine CsV3Sb5, whereas the out-of-plane componentdisappears with doping-induced suppression of charge density wave and global electronic nematicity. In addition, the Sb pz orbital plays an important role in both the pseudogap and superconducting states in CsV3Sb5. Our findings offer new insights into multiorbital physics in quantum materials that are generally manifested with intriguing correlations between atomic orbitals and symmetry-encoded correlated electronic states.

Discovery of a long-ranged charge order with 1/4 Ge1-dimerization in an antiferromagnetic Kagome metal

Jiakang Zhang
University of Science and Technology of China

Exotic quantum states arise from the interplay of various degrees of freedom such as charge, spin, orbital, and lattice. Recently, a short-ranged charge order (CO) was discovered deep inside the antiferromagnetic phase of Kagome magnet FeGe, exhibiting close relationships with magnetism. Despite extensive investigations, the CO mechanism remains controversial, mainly because the short-ranged behavior hinders precise identification of CO superstructure. Here, combining multiple experimental techniques, we report the observation of a long-ranged CO in high-quality FeGe samples, which is accompanied with a first-order structural transition. With these high-quality samples, the distorted 2 × 2 × 2 CO superstructure is characterized by a strong dimerization along the c-axis of 1/4 of Ge1-sites in Fe3Ge layers, and in response to that, the 2 × 2 inplane charge modulations are induced. Moreover, we show that the previously reported short-ranged CO might be related to large occupational disorders at Ge1-site, which upsets the equilibrium of the CO state and the ideal 1 × 1 × 1 structure with very close energies, inducing nanoscale coexistence of these two phases. Our study provides important clues for further understanding the CO properties in FeGe and helps to identify the CO mechanism.

Yin-Yang vortex on UTe2 (011) surface

Yuanji Li

USTC

UTe2 is a promising candidate for spin-triplet superconductor, yet its exact superconducting order parameter remains highly debated. Here, via scanning tunneling microscopy/spectroscopy, we observe a novel type of magnetic vortex with distinct dark-bright contrast in local density of states on UTe2 (011) surface under a perpendicular magnetic field, resembling the conjugate structure of Yin-Yang diagram in Taoism. Each Yin-Yang vortex contains a quantized magnetic flux, and the boundary between the Yin and Yang parts aligns with the crystallographic a-axis of UTe2. The vortex states exhibit intriguing behaviors - - a sharp zero-energy conductance peak exists at the Yang part, while a superconducting gap with pronounced coherence peaks exists at the Yin part, which is even sharper than those measured far from the vortex core or in the absence of magnetic field. By theoretical modeling, we show that the Yin-Yang vortices on UTe2 (011) surface can be explained by the asymmetric vortex-derived local distortion of the zero-energy surface states associated with spin-triplet pairing with particular d-vectors. Therefore, the observation of Yin-Yang vortex confirms the spin-triplet pairing in UTe2 and imposes constraints on the candidate d-vector for the spin-triplet pairing.

Observation of Superconductivity with BKT Transition and Self Doping Effect in Parent Infinite-Layer Nickelate PrNiO2

Yutong Chen
fudan univesity

For infinite-layer nickelate thin films, several studies have shown a key similarity to cuprates: their superconducting critical temperature vs. chemical doping phase diagram features a distinct dome shape. Herein, we showcase a superconducting state in undoped $PrNiO_2$ thin films, which were epitaxially grown on $SrTiO_3$. The samples are in clean limit without strong disorder scattering, confirmed by thermoelectric measurements. In addition, BKT transition is observed, indicating a limited superconducting depth in the extremely thin 2D system. Furthermore, ARPES investigations revealed 9% hole doping for Ni 3dx2-y2 orbital, which is in the superconducting dome of hole-doped cuprates. These results suggest parent infinite-layer nickelate thin films are superconducting with self doping effect, providing clues for establishing a unified framework for understanding unconventional superconductors.